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ABSTRACT

Programed instruction in the Soviet Union is based on the sequential delivery of questions and automatic evaluation of responses. Programs may be linear or may provide for branching that accommodates differences in individual learning styles. Computer models have been developed to simulate job functions and to teach speed-reading. Their use can resolve the following general pedagogical problems: (1) student control over the pace of learning, (2) monitoring of the student, (3) administration of exams, (4) consultation and referral, (5) tutoring, and (6) training. Flowchart conceptions of these processes are provided, and two automated teaching programs are described. (EMH)

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TEACHING MACHINES DISCUSSED

- USSR -

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TEACHING MACHINES DISCUSSED

- USSR -

Following is a translation of three selections in the Russian-language book Avtomatizatsiya proizvodstva i promyshlennaya elektronika (Automation of Production and Industrial Electronics), Vol 2, Moscow, 1963. Complete bibliographic information accompanies each selection.

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THE TEACHING MACHINE

[Following is a translation of an item by G. Pask and T. I. Rostunov in the Russian-language book Avtomatizatsiya Proizvodstva i Promyshlennaya Elektronika (Automation of Production and Industrial Electronics), Vol 2, Moscow, 1963.]

The teaching machine is a machine used to teach people facts and skills. The students must learn facts (such as mathematical formulas or, generally speaking, the principles of solving problems) and practical skills (dexterity, workmanship) based on the application of factual knowledge.

Usually the human-instructor teaches facts and helps the students gain skills (dexterity, workmanship). But in each case he can often be replaced by a teaching machine. At times machine teaching is more effective than the best teaching provided by a human; the most effective teaching presumes an individual approach and attention to each individual student. For this purpose, it is impossible to have a sufficient number of instructors, but any number of teaching machines can be made available.

Teaching facts. The teacher must inform and question (check how the material presented has been assimilated). Therefore, any type of instruction requires programs, the development of test questions, and the preparation of materials (in written form and in the form of graphs or illustrations) describing principles (for example, the presentation or solution of formulas or the understanding of valence in physical chemistry), as well as examinations to determine whether or not the students have mastered these principles. If the teaching is mechanized, the educational material is either projected on a screen or is demonstrated by means of automatic card display. It is convenient (this does not pertain only to the Skinner technique, which will be described below) to use questions requiring the selection of an answer (after each question the student is presented several alternative answers labeled, for example, A, B, C, D).

In this case, if the machine knows the correct answer to each question (in coded form or on punch or magnetic tape), it can immediately compare the student's answer with the true answer and explain any discrepancy. In addition to showing the student the training material, he can be informed of the results of a check of his knowledge or how he is improving.

Machines for teaching facts offer a sequence of training material sections and information on the results of training (not necessarily!) in the form of a programmed formula for comparing tasks. The design of these machines depends on the limitations imposed on the programmer. Many of these are mechanically trivial (they are useful, nevertheless, since simple types of programs also prove to be effective). The most versatile of available devices is the "Self-Tutor."

Methods of programming. In the simplest programs first used in the 1920's by Pressey and his co-workers, sections of training material were placed in a previously determined sequence which was empirically accepted as "optimum." If the student successfully mastered a given section, he was given the next section in the series, and if not, he was given the same section again. The entire sequence could be repeated. A step forward in this respect are such machines as Briggs' "Subject Matter Trainer." They are designed in such a way that when an entire series of sections is repeated, those sections which were successfully mastered are omitted. Skinner avoids programs of the sequence type where the student is presented complete information on the results after each step. He breaks down the material into very small meaningful units in order to reduce the percentage of wrong answers, proceeding from the fact that the teaching process is accelerated when the percentage of wrong answers by the student is small. Since the rate of study is controlled by the person using the machine, the student who has a good basis rapidly completes the course and, in any case, is not bored. Skinner prefers independent answers (the student writes his own answer and does not select it from a list of alternatives), since alternatives can suggest impossible answers. In this case, however, the system can only be partially mechanized.

Next are differentiating programs which involve a specific form of correction based on a more detailed comparison of factual and ideal answers to questions (solutions of problems). If an error is made, the machine, instead of a simple repetition of the section, presents a corrective sequence of sections chosen in accordance with the nature of the error.

To any of these methods may be offered the reproach that an "optimum" sequence is predetermined. In practice, individual differences between students may predominate, and an optimum method of teaching may be suitable only for a certain category of people; however, the characteristics of the participants are not known beforehand. Correspondingly, some differentiating programs have a more complex structure. They consist of a series of parallel subprograms suitable for any type of student, and the interrogation (checking) procedure involves a choice of not only the required correction but also a more effective subprogram, taking into

consideration the individual peculiarities of the student.

Machines capable of performing the required re-processing of information are costly; therefore, it is advantageous to use a computer as the centralized device with peripheral control desks for the display of material and to provide answers. The most improved system is the "Plato" teaching machine at the University of Illinois. The material is shown on a television screen and the student gives his answer using a keyboard-type of instrument. A similar apparatus is being developed by the System Development Corporation. It is expected that centralized apparatus will replace teaching machines for individual study. In any case, it is necessary to provide for memory registers to memorize the behavior of each individual.

Results of experiments. It is not easy to evaluate teaching machines, for, while the results of their utilization are significant, these same results often cannot be compared. The best programs are, to a great extent, based on intuition. Therefore, there is no clear determination of the problems which a program may perform nor criteria on the basis of which it would be possible to evaluate its fulfillment of these problems. Too little is known about how people study in school, and one of the virtues of teaching machines lies in their potential capabilities (when equipped with memory and recording devices) as a source of systematically compared data. The present theoretical basis in this field is not satisfactory, although the works of Kane, Annett and Reed in England and a number of scientists in the United States is helping to improve it. Many programs are derived to a certain extent from the theory of conditioned reflexes of Pavlov and his followers, many others from the theory of conditioned operands, and some from the conceptions of Kh'yulyan [transliterated from Russian] psychology, but the theoretical basis of effective teaching is still unclear.

The results obtained show that a good program can cut teaching time in half without seriously limiting the capability to remember or apply the learned material, which is a very significant achievement. The relative merits of different types of programs depend on the nature of the training material as well as on human parameters such as the level of general preparation and individual peculiarities, but these relationships may be predicted only to a limited degree. And, finally, there is information that machine presentation of programmed material is considerably superior to other methods.

Teaching skills. In teaching skills (dexterity, workmanship), the training program consists of a series of problems typical of situations encountered in real life in the performance of functions which require certain skills. The participant is required to solve these problems by a method satisfying certain criteria of evaluating his work. Although the problems included in the training process are a logical form of problematical situations in real life, they are often simplified. Thus, for

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example, the student may receive information which partially predetermines the correct solution of a problem, or he may be allowed more time for the solution of the problem than would be available in practice. If the demands of a skill can be formulated, then it is always possible to determine the measure of ability (proficiency) on the basis of the performance of the student in his fulfillment of the training program. And, since the sequence of problems is analogous to the sequence of sections of a study program (differing only in that the basic principles are assumed to be already known), then this measure of ability is analogous to the result of interrogation.

The apparatus used for teaching is a model. For training pilots, the model is an aircraft, and for training industrial engineers, it is some model of a piece of equipment which they must service. But the model should not be confused with the teaching machine, which, as the instructur, itself acts on the model for the purpose of modifying its parameters; for example, in teaching the operation of equipment, for determining what malfunctions (which the student must eliminate) might appear in the actual equipment. Generally speaking, the teaching machine determines the type of problem which is presented, the place in the training program where this problem appears, and the degree of simplification of the real-life (modelled) situation. The machine determines all of this as a function computed through discrete time intervals of the measure of ability (proficiency) of the student. If this function is previously determined, then the corresponding machine will be simply a more specialized model. It would be rational to build such a machine if we knew that the characteristics of the student were invariant and that individual differences did not exist. But experience contradicts these hypotheses at least in teaching the majority of skills.

Therefore, systems of teaching skills are often self-adjusting devices which, first, experiment with different conditions of teaching (training) and then adjust these conditions in order to maximize the appropriate index of the skill of the student. There are, for example, several American machines (called "adaptive vehicle simulators") which adjust the parameters of a tracking problem in an information feedback network in such a way as to minimize the average deviation from the predetermined course of a simulated vehicle guided by the student.

In the author's laboratory (England) work was being carried out as early as 1954 on self-adjusting teaching systems using a cybernetic approach. Teaching is viewed as the control of a training process. However, unlike the majority of control systems, we may assume in this case that continuous information feedback links the student with the model. This is in fact the case only with the condition that the attention of the student is maintained; therefore, a necessary feature of a high-quality teaching system must be the creation of an interesting (from the student's viewpoint) situation. Further, the system must strive toward a maximization of the rate of training the student. These procedures are, in fact,

inseparable, since the student "plays" with the adaptability of the system. The interaction of man and machine takes on the logical character of a "mute" conversation in which stability is achieved through compromise between the man and the machine.

Self-adjusting systems. One of the simplest self-adjusting machines is used to teach the skill of "rapid reading" -- this reading technique used in America involves the very rapid reading (scanning) of written material and extraction of significant information. Usually, a group of students is taught this skill using a special projector which shows fragments of a text (often half a line) in sequence, so that eye movement, called back tracking, is eliminated. The scanning speed and the length of the text fragments are controlled by the instructor on the basis of results of periodic conprehension tests. The instructor may also introduce different types of texts, such as technical reports on various subjects.

The teaching machine is an individual device. In front of the subject is an illuminated screen on which fragments of the text appear; to the side are several piles (two, in the simplest case) of drill cards X and Y. Above each pile is a signal light. When the light goes on the student must select a drill card (the text on the card is visible only when illuminated from behind) and place it in the machine. The sequence of text fragments is displayed at a speed determined by the self-adjusting part of the system. After the material has been "scanned," the questionnaire is illuminated with tests on comprehension. This is written on a card which also contains the coded image of the cirrect answer. The student completes the test and pushes a special button wihch denotes his selection of one of the alternative answers, after which the machine evaluates his achievements. When the test is completed, the student removes the card and places it in the completed pile, whereupon his action is recorded by an electrical circuit. Upon receiving the signal, the self-adjusting machine selects the signal light associated with one of the two piles of cards X and Y and determines the "scanning speed" parameter as a function of the result of the last test and the results obtained in previous tests when this same pile was used. This cycle is repeated until the student acquires good skill, while the training speed is somewhat increased.

This device illustrates some points of more complex systems. First, there is present the operation of simplification, namely, increasing the speed of displaying the text. In the teaching of many skills the effect of such reception depends on the stage of training which has been achieved and this must be detected by the machine. Furthermore, the machine can evaluate the ability (proficiency) of the student on the basis of the results of comprehension tests, and the rate of change of ability (proficiency), approximated as a function of differences, is a good indicator of the speed of training.

The strategy of teaching machines is the simplification of problems. Let us assume that the speed is increased infinitely (the maximum value of the operation of simplification). Then the material becomes incomprehensible (the maximum speed depends, finally, on the ability of the student at a given stage in the training). And, on the other hand, if the speed is reduced (maximum simplification), there is no improvement and the student becomes bored. Thus, a self-adjusting teaching machine must maintain the degree of simplification of the problem up to that limit at which the index of the speed of training is maximized. Under these conditions the student is primed by his own capabilities and his attention is maintained at the proper level.

There are special teaching machines for teaching the operation of office punch-card machines and the preparation of punched cards for computer input. In front of the student is a panel. After the teaching machine selects one of four training exercises consisting of a series of digits and letters, this series of printed symbols appears on the panel and a special indicator begins to move along the panel. The student's problem is to press the keys on a keyboard (resembling a typewriter keyboard) having those symbols on which the indicator comes to rest. The duration of the hesitation of the indicator is determined by the teaching machine relative to the speed of reaction of the trainee.

The simplification operation in this case consists of giving information, or prompting. On an auxilliary panel, which is an exact duplicate of the main keyboard, signal lights are lit above those keys which must be pressed on the main keyboard. The frequency of the "prompting" is determined by the success of the trainee -- at the beginning of the training period the display of the indicator is duplicated in full on the auxilliary signal panel, while after skill has been acquired, the signals are generally unlit.

In teaching skills of operating equipment, the types of problems correspond to types of malfunctions in the equipment being simulated; the simplification operation involves the presentation of additional information on the condition of the model which, in practice, the person concerned with repair would not have at his disposal. The achievements of the trainee are measured by comparing his actions with a logical optimum strategy (repair is simulated by the movement of electrical plugs in a panel which represent components of the equipment). A self-adjusting device for the mastery of this skill must have a hierarchy of at least two levels of control and must determine at least two series of conditional probabilities of the appearance of a malfunction. Other systems have been created for teaching such varied skills as the skill in making scientific deductions (inferences), coordinating sequences of conversions in repetitive sets, and applying solutions in production control.

Design limitations. A system may be built if it satisfies the conditions that: 1) the skill to be taught can be reduced to a finite number

of "subskills," each of which has a problem of "operation simplification," so that it is possible to determine the relative difficulty of the "subskill" at any stage in training and there are adequate criteria for the performance of these same actions; 2) the student conducts himself during training as a self-limiting system (which is a well-determined logical concept).

Conditions 1) and 2) can often be satisfied independently of the type of concrete training method. And if this is so, then this method can be stabilized on cybernetic principles through the maximization of the "speed of training" parameter, and the process fundamentally satisfies limitation 1). But condition 2) maintains that the student is a self-limiting system; thus, it is possible to avoid a special and difficult situation with the student and to operate with him as with a self-limiting system. At the same time, the term "teaching machine" may be a delusion. Such a self-adjusting system establishes its interaction with the student and, by observing concrete boundary conditions, it "teaches." With other boundary conditions it may "question" or "assist," helping in the formation of a skill (the appearance of ability).

Finally, there is the interesting possibility of group self-adjustment. Several experiments performed recently show that the interaction between a group of individuals can be directed by an automatic control device so that the members of the group rather effectively teach each other through correspondingly mechanized channels of reactions (answers). The automatic device does not teach in this case, but creates an organization in which the students are their own best instructors (teachers).

by G. Pask

Experience of application. Teaching machines are used to solve the following problems: individual study of a subject by a student with continuous self-control; collective teaching with continuous individual control of the actions of each student; the conduct of monitoring, examinations, tests, and colloquiums; the conduct of consultations without the presence of an instructor; individual learning of skills; an operative check of the preparedness of individuals before permitting them to work on complex machines.

Teaching machines are subdivided: according to the type of teaching (individual, group, and mass); according to the principles of programming (linear or branched programs); according to the function performed in the teaching process ("Controller," "Examiner," "Tutor," "Simulator," "Lecturer," "Consultant," and multiregime machines); according to the teaching principle (teaching in an open cycle -- without feedback, and in a closed cycle -- with feedback); according to design features (electromechanical, electronic, digital electronic, analog, and modeling machines); according to the method of input (selective, numerical, resultative, and combined); according to the method of action (on sight, hearing, or the

combined organs; according to the degree of influence on the course of the learning process (machines with little adaptability, average adaptability, and complete adaptability).

The functioning of any teaching machine is only a continuation of the actions of the instructor, that is, it has a secondary nature. The teaching machine has a significant influence on the improvement of the teaching process because of the fact that it permits the instructor to establish contact with each student, to provide systematic and continuous control over the teaching (self-teaching) process, and to provide systematic and active work for the student.

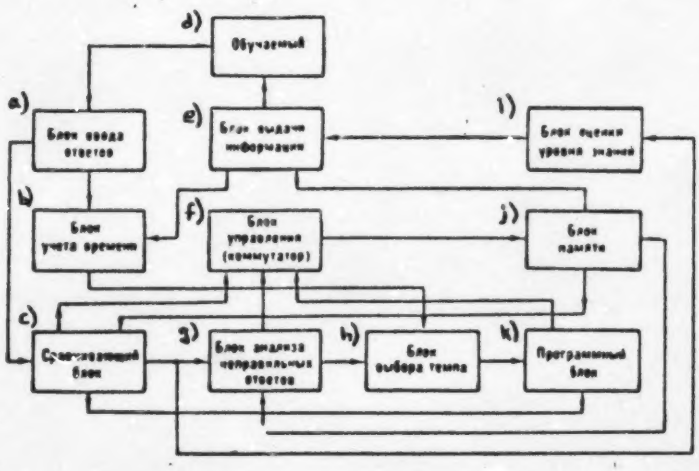

Fig. 1 Block Diagram of the "Repetitor" Teaching Machine

Legend: a) Answer input unit; b) Time counting unit; c) Comparator unit; d) Student; e) Information output unit; f) Control unit (commutator); g) Incorrect answer analysis unit; h) Speed selection unit; i) Level of knowledge evaluation unit; j) Memory unit; k) Program unit

Different types of teaching machines may have a different number of functional units. For example, the block diagram of a "Repetitor" (tutor) type teaching machine (figure 1) consists of 10 units. The information output unit presents the student with the necessary information concerning the task underlying the solution, provides methodical advice, or "hints," exhaustive explanations, an evaluation of results, etc.

The answer input unit provides feedback between the student and the

machine, that is, input of information into the machine concerning the level of achievement of the student in the form of answers to tasks and questions presented.

The time counting unit records and stores the time spent on all stages of the training (the presentation of information, solution of the problem by the student, input of the answer, etc.). The unit is also used for storing statistical material on the training process.

The memory unit stores all information on the subject being studied, including standard (correct) and the most likely incorrect answers. The unit is characterized by its memory capacity (from tens to thousands of units), its memory method (magnetic tape, slides, paper tape, disk and electrical charges, etc) and the time of information recovery -- the speed with which information is taken from the machine and presented to the student.

The program unit provides for, in accordance with the machine's program, extracting the required information from the memory unit and transmitting it to the comparator unit (which compares the student's answer with the standard answer stored in the memory unit), to the incorrect answer analysis unit (which analyzes incorrect answers and, according to the results of the analysys, acts on the training process), and to the information output unit.

The presentation of information to the student occurs differently in different machines. With a linear program, the order of presentation of information and questions is strictly determined and does not vary in the training process. In this case, the points of the program are taken from the memory in the same order in which they were entered. With a branched program, additional information is retained in the form of advice, "hints," or complete answers. In this case, the individual characteristics of the student and subject matter are better taken into consideration. The program encompasses several methods of solving a problem, and the teaching machine reacts correspondingly for each of these methods.

The control unit (commutator) automatically controls the operation of the teaching machine. The level of knowledge evaluation unit provides information over the feedback circuit between the teaching machine and student concerning the level of knowledge of the latter and informs him of this evaluation.

The speed selector unit for the conduct of tasks adjusts the machine to the level of knowledge and capabilities of the student (in the simplest machines, the speed of operation is determined by the student himself).

The effectiveness of teaching with a teaching machine depends on the principle of programming used in it. Figure 2 shows the programs of some

teaching machines which differ by the nature of their reaction to incorrect answers. Figure 2 a shows a linear program: the student is presented with problems 1, 2, 3 ... n. To each question may be given several answers (in this case, three), of which one is correct (11, 21, 31 ... n).

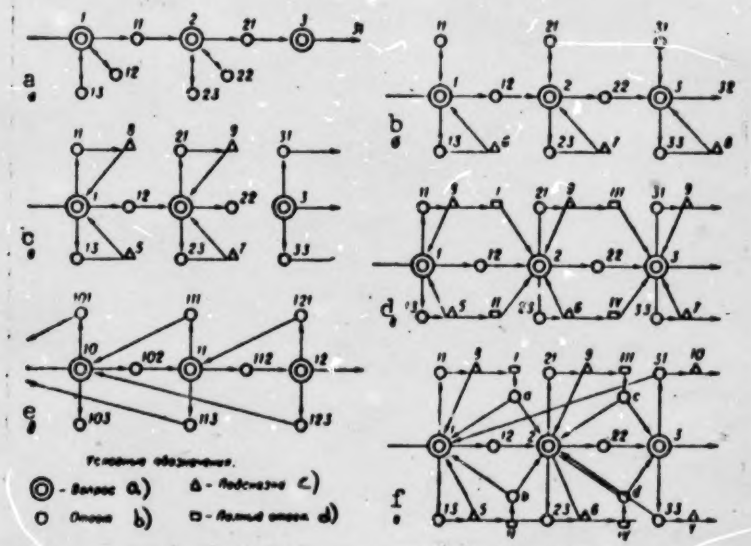

Fig. 2. Operating Programs of Teaching Machines

Legend: a) Question; b) Answer; c) Hint; d) Complete answer

Answers 12, 13, 22, 23 ... n2, n3 are incorrect. Only after selecting the correct answer does the machine move from the Kth question to K + 1. If an incorrect answer K2 or K3 is chosen, the machine recommends a return to the Kth question and attempts to obtain the correct answer. All incorrect answers are recorded by the teaching machine and are taken into consideration during the evaluation. Figure 2 b shows a program with a small branch permitting the teaching machine to carry out a certain "analysis" of the incorrect answers. Thus, after incorrect answer 11, 21, 31 ... K1, the student is again asked to answer questions 1, 2, 3, ... n, and after incorrect answer 13, 23, 33 ... K3, the machine gives a "hint" 6, 7, 8 ... n. After the "hint" the student is again asked to answer question K, and after a correct answer, he is asked to proceed to question K + 1.

The teaching process according to figure 2 c is similar, but in this case a "hint" is given for all incorrect answers. "Hint" 5 differs from "hint" 8. In the program of figure 2 d it is allowed that, if the student gave incorrect answers 5, 6, 7 ..., the teaching machine would give him exhaustive explanations (I, II, III ... N), after which he would be per-

mitted to move to the next question. A further development of branched programs is the program shown in figure 2 e. It is reversible; that is, after an incorrect answer to the Kth question, it permits the student to return to the previous questions (questions K1 or K2, etc.).

A branched program must provide: the possibility of analyzing incorrect answers and the provision of "hints" for the [illegible] of incorrect answers; the possibility of "reversing," that is, a return to questions already examined if it seems that the lack of knowledge will retard further teaching progress; the possibility of checking the student's comprehension of exhaustive explanations given by the machine. A branched program satisfying these requirements is shown in figure 2 f.

The greater the extent of branching, the greater the effectiveness of the teaching. However, a great degree of program branching complicates the design of the teaching machine.

The majority of teaching machines require the study of programmed material; some machines provide for study using existing textbooks and study aids. General instruction, special, and major disciplines are studied with the aid of teaching machines. Experience has shown that with the use of teaching machines, the activity and independence of the student in increased considerably, as a result of which his ability to succeed is also increased.

The development of teaching machines presents the following basic demands: simplicity of technical design, acceleration of the educational process, freeing the instructor from routine tasks, a rapid transition from one program to the next, simplicity of coding input data, rapidity of the output of teaching results, and documentation of the results of the educational process.

Further development of teaching machines is proceeding toward the creation of small machines based on micromodular elements, the creation of control attachments for standard projectors and tape recorders, the creation of teaching machines with sound and light effects, as well as machines which react to the voice of the student and provide information by voice. "Automatic teaching forms" based on simple cybernetic equipment and "teaching complexes" based on digital computers are being developed. Measuring apparatus make it possible to measure quantitative data on natural relationships which exist in teaching systems and to determine the influence of different factors on this process. The quantitative characteristics of the teaching process have an influence on the development of teaching theory.

The further development of bionics, information theory, and game theory and other sciences will lead to the creation of teaching machines which can truly be called teaching machines, since they will strengthen the mental activity of the students.

Some types of teaching machines are shown on a separate page. The automatic teaching control apparatus OKA-7-4 is designed for control (of a colloquium, tests in laboratory work, examinations, etc.) with programmed teaching. The task card (with no more than 10 questions) is placed on a panel. In order to move from one question to the next a switch must be turned, which indicates the number of the question on the panel. The number of answers to each question is not more than 5, of which one is correct and the remaining incorrect. The student gives his answer by pressing the button located opposite the answer he selects. If the answer is correct, a light goes on opposite the assigned question. The program changes when moving to the next question. When the answer is incorrect or when an attempt is made to press several buttons simultaneously, the circuit is blocked and further pressing of the buttons has no effect. The circuit is freed in moving to the next stage.

After the student has completed an entire task, the light indication cannot be changed until the instructor switches on a special toggle switch. An evaluation of the performed task can first be made from the card according to the number of correct answers or can be determined by the instructor on the basis of an analysis of the signal light indications.

The OM-1-2 control machine checks knowledge in practical subjects before laboratory work and is also used for self-control. Five questions are introduced (by means of a telephone dial) simultaneously into the machine. The answering sequence is arbitrary. The machine determines the correct answer and evaluates it according to a five-point system. The results of the answers are recorded by an electrochemical printer. The program may be changed by means of removable memory elements with a branch program. The OM-1-2 is designed with semiconductors and cold cathode paratrons.

The small K-2 teaching machine belongs to the class of control devices. Answer input is by a combined method -- resultative, numerically coded, and selective. The circuit of the machine is based on MT Kh-90 cold cathode thyratrons. A time limitation (3 or 10 minutes) for answering questions may be introduced into the machine. The possibility of the students changing the answer is eliminated. The machine operates on a 220-volt network and has a power consumption of 6 watts.

by T. I. Rostunov

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THE AUTOMATIC TEACHING FORM

[Following is a translation of an item by T. I. Rostunov in the Russian-language book Avtomatizatsiya Proizvodstva i Promyshlennaya Elektronika (Automation of Production and Industrial Electronics), Vol 2, Moscow, 1963.]

The automatic teaching form is a form designed for the automation of teaching processes with continuous individual control of the students in the teaching process. It is used with the constant participation of the instructor, who receives, after a brief time interval, information on the progress of each student. On this basis, he is operationally included in the teaching process and eliminates any shortcomings which are detected.

The combination of the simplest teaching machines with a system of communications in the automatic teaching form significantly increases the productivity of the instructor in comparison with the distinct application of teaching machines. As a result of such combination, teaching machines make it possible to carry out a greater number of different types of training exercises and make the training process more dynamic and controllable.

Automatic teaching forms have the following requirements: they must not disturb the natural thought process of the student while he is studying the material; the methods of input and output of questions and answers and the teaching "language" between the student and the machine must be as simple as possible; the equipment of the teaching form and operation with it must provide the maximum of independence and active performance in the teaching process. This performance must coincide with the actions of the students using ordinary methods of teaching and must provide for the control and recording of the teaching process for each individual student for the purpose of studying the processes and making the necessary corrections in them; the equipment and the teaching program used must provide for an operational evaluation of the actions of the individual student and the class as a whole; a situation must be created which generates maximum

interest on the part of the student toward the task which is assigned and the subject being studied; the results of teaching must be documented with the aid of printing devices; there must be minimum cost, simplicity of equipment, reliability of operation, and minimum electrical power consumption. Thus far, not all automatic teaching forms satisfy the above requirements.

The simplest in design and the most satisfactory on the basis of the above requirements is the OAK-6 teaching form (see figure on other page). It is designed for teaching 26 persons simultaneously, but can be expanded within reasonable limits. The form has an instructor's desk, students desks, a dual wall-mounted signal panel, a slide projector, a screen, a power supply system, coding tables, and a recording instrument.

The instructor's desk is used to establish the program of the correct answer for all students, permits individualized control of the progress of answer formation and preparation by each student, and provides remote control of the projector and screen. The desk has a relay which limits the time alloted the students for the preparation of answers.

The student's desk is designed for the input of answers, for communication to the instructor's desk concerning the readiness of answers, and for receiving signals from the instructor's desk if the student has given a series of incorrect answers or has not replied in the alloted time. The desks of the students and instructor have two-way communication.

The wall-mounted signal panel (see diagram on other page) is a duplicate of the signal panel on the instructor's desk. It simultaneously gives the results of the answers of all students. When the time alloted for an answer runs out, the instructor switches on the lights on the panel and verifies the correct answers of the students. At the same time, the students desks are turned off from the instructor's desk and the signal panel, making it impossible for the students to make corrections from the wall panel. Each student sees the results of his work on this signal panel.

Study material in the form of different texts, problems, examples, and questions for the students are shown on the screen with the aid of the projector. The screen, which is of white linen 2 x 2 meters in size, is attached to an aluminum tube 25 millimeters in diameter which turns by means of reduction gearing from a 250-watt ac motor.

The coding table on the next page is used in compiling answers involving the use of mathematical formulas and dimensional values.

Similar tables may be developed for any subject. For practical purposes, the tables are suitable for foreign languages, physics, radio engineering, mathematics, complex systems diagrams, etc. It is only necessary to replace the coding table when changing from one subject to another.

The recording instrument is self-recording and records the teaching process for each individual student. With the record made by this instrument it is possible to follow the dynamics of the actions of the students in the process of answer formation. The instrument "records" the teaching process from which the necessary analysis can be made.

No	Dimen. value	Sign of action	Coordinates	Elec. symb.	Elec. units and values	Trig. functions, etc
1	,	Σ	β	R	a	sin
2	÷	$\int$	ε	L	v	cos
3	rpm	=	η	C	p	tg
4	min	$\frac{d}{dt}$	j	Q	f	ctg
5	sec	+	i	τ	pF	sec
6	m/sec	-	k	μ	cps	cosec
7	m	:	D	c	ohm	arcsin
8	km	$\sqrt{}$	x(a)	ω	hy	arctg
9	deg.	$(\ )^n$	y(b)	t	U	ln
10	w	( )	z(c)	π	I	lg

Coding Table

The OAK-6 is simple in construction, reliable in operation, and does not require special preventive maintenance. The shortcoming of this teaching form is the impossibility of using the student's desk autonomously as in ordinary teaching machines, as well as the single work program for all the students desks.

All students answer the instructor's questions from their own desks. Since the actions of each student are evaluated immediately after they have formed an answer, the actions of the students approximate their actions when taking tests and examinations according to the usual teaching method. The student is continually active in the teaching process, and at the end of each exercise the instructor has complete information on the achievement of each student.

The following types of studies may be carried out with the OAK-6: lectures, drills, seminars, test work and examinations. The reading of lectures with the automatic teaching form differs somewhat from lectures read in the usual manner. The lectures are broken down into complete logical parts; after reading each part, the lecturer presents a question to the entire audience. The questions are presented in the same manner as in the usual teaching method. Each student answers the question from his own desk. At the end of the time alloted for the answer, the instructor presents the results on the signal panel. Thus, during the lecture, the lecturer is able to make several checks on how his audience is assimilating the lecture material and whether or not he is presenting the material in a sufficiently profitable manner. The students, knowing that each of them will be brought to account for each part of the lecture while the lecture

is being read, will listen and take notes more carefully. Therefore, the lectures proceed with a great deal of activity. The recording device records the actions of each student on the basis of time, which makes it possible to explain the nature of the actions of the students in their formation of answers and, correspondingly, to influence them. In the case of drills performed with the automatic teaching form, each student must solve all the problems, and the correct and incorrect solutions of each will be shown immediately to the entire class and evaluated by the instructor. Experience shows that students using the automatic teaching form solve more problems than in an ordinary class and are more responsive to the task. Text material may be put in drill form in greater volume than usual, and its assimilation is greater.

The method of presenting questions and compiling answers is the same in seminars as in lectures and drills. After the answers have been received and the results are displayed on the signal panel, they are discussed by the students themselves. The instructor calls on a student and asks him to explain why he answered a given question in one way rather than another. Experience shows that seminars with the automatic teaching form are more active, more qualitative, and more purposeful than in the ordinary class. When tests and examinations are given with an automatic teaching form, the instructor receives the results of the work of each student at his desk or in written form.

At the present time automatic teaching forms are being developed and introduced on the basis of still other patterns. Their broad application in the educational process will provide the possibility of determining which of these are the more optimum.

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THE TEACHING COMPLEX

[Following is a translation of an item by T. I. Rostunov in the Russian-language book Avtomatizatsiya Proizvodstva i Promyshlennaya Elektronika (Automation of Production and Industrial Electronics), Vol 2, Moscow, 1963.]

The teaching complex is a complex of technical devices designed for the automation of teaching processes according to the maximum possible branching of the program, both with and without the immediate presence of an instructor. The use of programs with a great deal of branching makes the teaching complex more effective in comparison with individual teaching machines and automatic teaching forms. The teaching complex is designed on the basis of the digital computer. The number of students that can be taught simultaneously depends on the capacity of the memory unit and the speed of the computer.

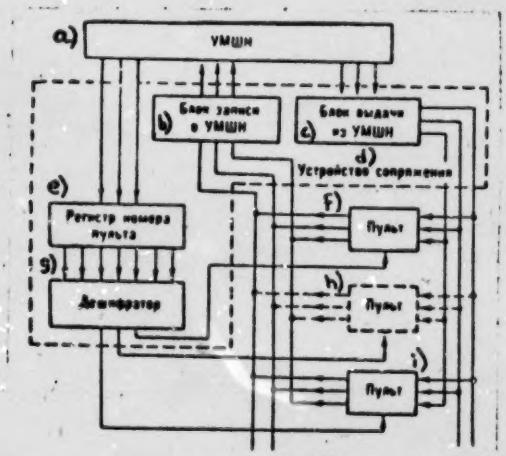
An experimental model of the "Radon" teaching complex, designed on the basis of an electronic digital computer called a broad purpose control machine [upravlyayushchaya mashina shirokogo naznacheniya -- UMShN] can be used to teach 25 persons simultaneously. It is expected that the number of students can be increased to 120-150 with simultaneous teaching of three to four subjects. The "Radon" (see figure) consists of: an UMShN, the students desks, the computer read-in and read-out units, a unit to record the number of the desk, a decoder, and the instructor's desk.

The UMShN (see figure) is built with semiconductor elements, is small in size, and requires comparatively little power (1.5 kwh).

The function of the student's desk is to unite the student with the machine. The number of desks corresponds to the number of students, which makes it possible to conduct independent teaching of each student at the rate at which he is capable. The student receives an assignment from the UMShN and upon completing it, enters the results of the solution into the machine. The independence of operation of the desks is achieved by the

presence of a device which links the computer with the desks. It can connect all desks to the UMShN in turn, receive the information, and send the results of the teaching process to the desks. The machine can question and give information to 25 desks in no more than 0.3 seconds.

The read-in unit takes the results of the student's decision from the desk and records them in the memory unit of the machine. The read-in and read-out units are connected in sequence by the decoder to each desk. Signals coming from the desk-number recorder serve as the input information for the decoder; selective switching to the required desk is carried out according to the code supplied by the desk-number recorder.



Block Diagram of the "Radon" Teaching Complex

Legend: a) UMShN; b) UMShN read-in unit; c) UMShN read-out unit; d) Linking device; e) Desk-number recorder; f) Desk; g) Decoder; h) Desk; i) Desk

The read-out unit reveals the progress of the teaching process for each student through the desk-number recorder, which distributes the information from the machine to the appropriate student's desk. The instructor's desk can, at any moment, control the teaching process, receive information on the stage of the teaching process, the time spent by the student on the program, how many and what type of errors he has made, and can evaluate the student's knowledge. If the student has exceeded the permissible number of errors or has not responded in the required time, his desk is disconnected from the machine and a signal light goes on at the instructor's desk.

In using the teaching complex the student is given a formulated rule, the application of this rule is illustrated by two or three examples, after which several problems or examples are given for independent solu-

tion. All of the original study material is contained on special cards having their own number (code). The code for each card as well as the answers to problems and examples presented to the students are stored in the memory unit of the machine. Once the student has solved a problem, he enters the results of the solution into the machine, which compares the answer with the standard answer stored in the memory unit. If they coincide, the signal light "correct" and the number of the card with which he should continue the study are displayed at the student's desk. If the answers do not coincide, the "incorrect" signal goes on and the number of the card containing the rule on which the error was made is displayed. An account is kept of both the number of errors made on the given example and the total number of errors made by the student. If the number of errors made in solving a given example exceeds the maximum permissible number, the signal light "end of study due to number of errors" comes on and that desk is disconnected from the machine. If the student spends more than the alloted time on the study of a given card, the machine turns on the signal light "end of study due to time." The student may continue the traning process only after the permission signal is given from the instructor's desk.

The student establishes the number of the first card from his desk in the task interrogation mode. Further, in the teaching mode the program is conducted from the cards in sequence in the order of increasing numbers. In order to skip a card or return to a card, it is necessary to know the number of the required card.

In the event that the student uses the wrong number card or if the student omits some step in the program without the permission of the instructor, the program sends the signal "verify the number of the card" to the student's desk.

In taking an examination, the student must solve the examples given on the cards whose numbers are relayed to his desk according to the program. Only the signal "end of examination" is given at the student's desk; this is given after he has solved all of the examples or if he has not completed the examination in the alloted time. The end of the examination is indicated at the instructor's desk by a light. The student notes the correctness of his answers on each point in the examination by comparing the answers with the results obtained in the machine, which has carried out computations in parallel with the students. If the answers do not match, the total in the error counter is increased by one, and the incorrect answer plays a part in further calculations by the machine on the given example so that the effect of an error once made is not overlooked in subsequent comparisons of the students answers with the results of machine calculations. The number of errors made by a student is the basis for evaluating his achievements. The number of errors made on an individual subject is used to determine the less easily assimilated questions which require the attention of the instructor.

The prospects for the use of the teaching complex in programmed teaching are essentially unlimited. The teaching complex may develop along several lines: a) improvement of the read-in and read-out device. The most advantageous link between the student and the machine is by voice or in ordinary written form. A read-in device representing a "filmoscope" with automatic selection of any frame has been created. The programmed material with the text, questions, and hints is carried on a strip of film with 128 frames. Later, slides were developed having a capacity of 1,000 frames. Depending on the student's answer, the machine issues a command which is read into the "filmoscope." The automatic circuit selects the required frame and projects it on a screen. The optical system is designed for operation in a lighted auditorium, facilitating the use of textbooks and notebooks. Electric typewriters should be used at the desks to improve communication between the students and the machine. They are noiseless and permit rapid read-in of both numbers and letters;

b) improvement of computers designed to operate with teaching machines. The most advantageous for this purpose would be the development of specialized digital computers which would differ from universal computers by the large capacity of their memory units, speed, and a special command system. Such machines would be less complex than universal machines due to the simplification of the addition and multiplication units;

c) improvement of teaching programs. The programs must provide simultaneous teaching of the greatest possible number of subjects; that is, the program must be as universal as possible. In addition, the logic of the program must be sufficiently flexible to provide more effective individual teaching.

Bibliography: Programmirovannoye obucheniye i kiberneticheskiye obuchayushchiye mashiny (Programmed Teaching and Cybernetic Teaching Machines), Moscow, 1963.

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